SOME FEATURES OF THE GROSS ANATOMY OF THE SPINAL CORD AND NERVE ROOTS, AND THEIR BEARING ON THE SYMPTOMATOLOGY AND SURGICAL TREATMENT OF SPINAL DISEASE.[1]

By Charles A. Elsberg, M.D.,

PROFESSOR OF CLINICAL SURGERY IN THE UNIVERSITY AND BELLEVUE HOSPITAL MEDICAL COLLEGE, NEW YORK.

During the last year I have made a number of dissections of the human spinal cord, nerve roots, and membranes in order to study their arrangement and relations. Some of the observations made are recorded in what follows.[2]

The Structure of the Posterior Roots as the Explanation for the Peculiarity of Root Symptoms at Different Levels. As is well known, the anterior and posterior nerve roots perforate the dural sheath separately, with a thin septum of dura mater between them. In the cervical region (Fig. 1, *A*) the nerve bundles of the posterior roots remain distinct until they have passed through the dura. The bundles are spread out like a fan, the broadest part being at the cord. At their origin the bundles are spread out so as to occupy 1 to 2 cm. of the cord; between their origin and the dura they lie closer together, forming a layer 1 to 1½ cm. broad; at the dural openings the nerve bundles are still distinct. In the dorsal and lumbar regions the arrangement is different from that just described; the separate bundles soon combine to form one bundle (Fig. 1, *B*), which passes outward to the dural opening as the posterior root.

From this arrangement it is clear that in the cervical region a tumor will, for a long time, make pressure only upon a few of the bundles which go to make up a posterior root. In the dorsal and lumbar regions the nerve bundles are united into one nerve near the cord; a tumor in these regions will press upon the whole nerve root from the beginning. Clinical experience agrees with these anatomical facts: the earliest symptoms of pressure upon a cervical nerve root are usually confined to a small area of distribution, one or two fingers for example, while in the dorsal or lumbar region the classical root symptoms extend over entire root areas. It is more exact therefore to distinguish between "root bundle" and "root" symptoms, and this distinction should be of clinical value.

The Intradural and Extradural Course of the Posterior Roots and its Significance. A careful dissection of the posterior roots of the spinal cord will show that there are very marked differences in their course at different levels. In the cervical and upper dorsal regions the nerve bundles unite to form the posterior root and pass out of the dural sac at almost a right angle to the cord. They then perforate the dura and enter the posterior ganglion (Fig. 2, *A*). From the ganglion each root passes outward with a slight inclination upward.

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[1] Read at the October (1912) meeting of the New York Neurological Society.

[2] The dissections were done in the anatomical laboratory of the Fordham University Medical School.

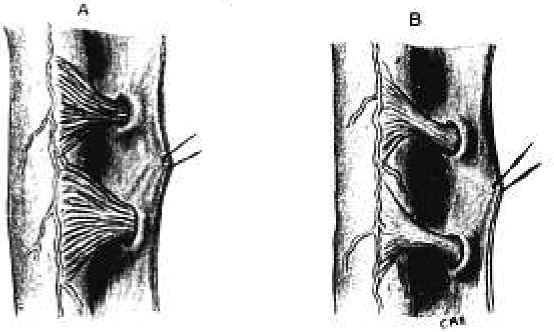

Fig. 1.—*A*, two cervical posterior roots; *B*, two dorsal posterior roots.

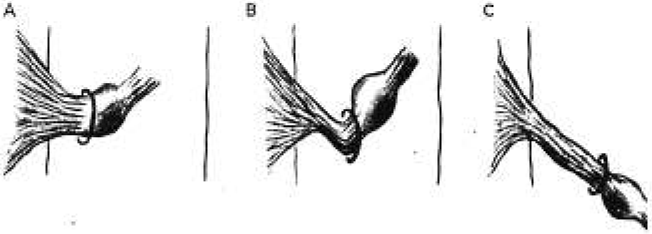

Fig. 2.—The course of the posterior spinal roots. *A*, cervical; *B*, dorsal; *C*, lumbar. Note the marked angle of the dorsal root just before it perforates the dura.

From the eighth cervical to the middorsal region the course of the posterior roots is different. Each root has an inclination downward until it nears the dura; it bends upward at an angle just as it perforates the dura. In the middorsal region this angle is often very acute—40° to 45° (Fig. 2, *B*). Beyond the ganglion each posterior root passes markedly upward before it divides into its anterior and posterior branches.

In the lower dorsal and lumbar regions the posterior nerve roots pass downward and outward and perforate the dura; beyond the ganglia the direction remains unchanged until the nerve roots divide into their anterior and posterior branches (Fig. 2, *C*).

It is easy to understand, when one considers the striking angle in the posterior roots in the dorsal region, that only a slight inflammatory process near the dural opening may be responsible for the occurrence of marked root symptoms.

It is probable that the movements of the vertebral column (bending backward and forward) will increase an existing pressure upon any of the lower dorsal and lumbar posterior roots, because these cannot yield as easily as the upper dorsal roots. Root symptoms in the lower dorsal and upper lumbar regions should become much intensified with forward and backward movements of the vertebral column. To a less degree this must also be the case in the cervical region, although here the bundles of the posterior roots are spread over such a large area that all are seldom pressed upon at the same time. Lateral movements of the spine are apt to increase a root pain on the opposite side and to lessen a root pain on the same side to which the spine is bent. These facts probably have an important bearing upon the occurrence of rigidity of the spine, which is found in patients who have a tumor in the lower dorsal and upper lumbar and also in the cervical cord.

The Relation of the Ligamentum Denticulatum to the First Lumbar Root and the Surgical Importance of this Relation. The ligamentum denticulatum is a fibrous band which is derived from and attached to the lateral aspect of the pia mater on the cord midway between the anterior and posterior roots. On each side of the cord the ligament extends from the foramen magnum to the level of the first lumbar vertebra. From its attachment to the cord each ligament extends outward and is attached to the inner surface of the dura by numerous dentations or slips. This ligament divides the subarachnoid space into an anterior and posterior compartment. It is due to this ligament that a tumor which grows on the anterolateral or posterolateral aspect of the cord will press upon only anterior or posterior roots for a long time, and thus give only anterior or posterior root symptoms before the appearance of symptoms of pressure upon the cord itself.

The dentate ligament ends below, at the level of the first lumbar vertebra, in a fork-shaped extremity (Fig. 3, *L, D*). The outer prong of the fork is usually about 1 cm. long, and is attached by its end to the inner surface of the dura. Sometimes this prong is 3 or 4 cm. long. The inner prong of the fork is attached to the pia on the lateral aspect of the cord and is prolonged downward along the side of the conus to its tip.[3] The first lumbar posterior root rests upon this fork (Fig. 3), so that the "fork" may be used as an anatomical landmark for the identification of the first lumbar root. The posterior roots of the lumbar and sacral nerves are dorsally placed with reference to the fibrous band on the side of the lumbosacral cord and conus derived from the dentate ligament, and can be easily raised up with a probe which is bent to a slight curve. At their origin from the lumbosacral cord the posterior roots lie close together, but when they are raised up with the probe the separate roots can be recognized. If one begins to count from the posterior root which lies on the fork of the dentate ligament, which is the first lumbar, one can easily identify each posterior root.

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[3] The filum terminale is described in the text-books as derived from the pia mater of the cord. It is really the prolongation downward of the inner prong of the fork of the dentate ligament, and is formed by the fusion of the downward prolongations of the ligaments of the two sides.

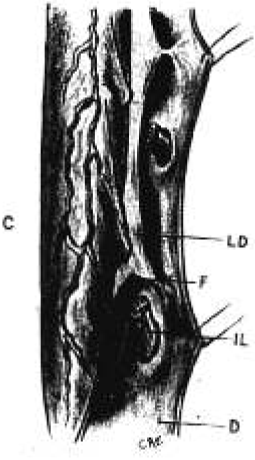

FIG. 3.—The lower end of the ligamentum denticulatum. *LD*, showing the "fork," *F*; *C*, conus; *D*, dura laid open; *IL*, first posterior lumbar root. The root has been divided to show the fork of the dentate ligament.

The importance of these anatomical facts for the operation of division of posterior roots to the lower extremities is clear. In this operation it is usually necessary to divide four or five posterior roots on one or both sides, and, therefore, four or five laminæ have to be removed so that the roots can be identified at the points where they perforate the dural sac. Sometimes it is not easy or certain that one has separated the posterior from the anterior root. To avoid this extensive laminectomy, van Gehuchten, Codivilla, and Wilms and Kolb have suggested that the nerves should be exposed at their origin from the lumbosacral cord by the removal of three laminæ in the dorsolumbar region. According to these authors, however, it is difficult to recognize the roots to be cut, and there is danger of division of the anterior roots with the posterior ones.

Based upon the anatomical facts above described, I have, in the cadaver, exposed the lumbosacral cord by the removal of the laminæ of the eleventh and twelfth dorsal or eleventh and twelfth dorsal and first lumbar vertebræ, and have been able to recognize and divide the lumbar and sacral posterior roots desired. I desire to recommend the following method for the exposure and division of posterior roots to the lower extremities: Removal of the spinous processes and laminæ of the eleventh and twelfth dorsal vertebræ (and of the first lumbar if necessary) in the usual manner; exposure of the "fork" of the dentate ligament and identification of the first lumbar posterior root; careful elevation of all of the posterior roots of the side to be operated upon (which lie dorsal to the lateral fibrous band on the side of the lumbosacral cord) upon a bent probe passed under them; identification and isolation of the desired posterior roots by counting from the first lumbar root; division of the roots in the usual manner.

BENCE-JONES PROTEINURIA: A REPORT OF FOUR CASES, WITH SOME CHEMICAL AND BIOLOGICAL NOTES.[1]

By Thomas R. Boggs, M.D.,

ASSOCIATE PROFESSOR OF MEDICINE, JOHNS HOPKINS UNIVERSITY; PHYSICIAN-IN-CHIEF, CITY HOSPITAL AT BAY VIEW,

AND

C. G. Guthrie, M.D.,

INSTRUCTOR IN MEDICINE IN CHARGE OF THE CLINICAL LABORATORY; ASSISTANT RESIDENT PHYSICIAN, THE JOHNS HOPKINS HOSPITAL, BALTIMORE

(From the Clinical Laboratory of the Johns Hopkins University and Hospital.)

I. Introduction. Having had the unusual opportunity of studying, with more or less completeness, 4 cases of Bence-Jones proteinuria, it seems to the writers worth while to record these briefly with some observations on the methods of recognition, chemical properties of the body, and certain biological reactions. The work of Magnus-Levy,[2] Grutterink and de Graaf,[3] Abderhalden and Rostoski,[4] and especially the recent exhaustive con-

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[1] Read at the meeting of the Association of American Physicians, May 14, 1912.

[2] Zeit. f. phys. Chem., 1900, xxx, 200.

[3] Ibid., 1902, xxxiv, 393; ibid, 1905, xlvi, 472.

[4] Ibid., 1905, xlvi, 125.